Communication Systems Simulation Laboratory (CSSL)

Simulation Planning Guide

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

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1.0 Introduction

The Johnson Space Center (JSC) has created and refined innovative analysis, design, development, and testing techniques that have been demonstrated in all phases of spaceflight. JSC is uniquely positioned to apply this expertise to components, systems, and vehicles that operate in remote or harsh environments. We offer a highly skilled workforce, unique facilities, flexible project management, and a proven management system.

1.1 Purpose

The purpose of this guide is to acquaint Requesters with the requirements for test, analysis, or simulation services at JSC. The guide includes facility services and capabilities, inputs required by the facility, major milestones, a roadmap of the facility's process, and roles and responsibilities of the facility and the requester. Samples of deliverables, facility interfaces, and inputs necessary to define the scope, cost, and schedule are included as appendices to the guide.

1.2 Facility Availability

JSC facilities are available for the National Aeronautics and Space Administration (NASA), other government agencies, and commercial requesters. We have developed user-friendly agreements to streamline business relationships and are eager to share our unique facilities and expertise. We invite your inquiries regarding application or adaptation of our capabilities to satisfy your special requirements. Briefings on general or specific subjects of mutual interest can be arranged at JSC or at your business site.

1.3 Inquiries

General inquiries regarding the use of JSC facilities should be directed to:

JSC Engineering Directorate
Johnson Space Center
2101 NASA Parkway, Houston, TX 77058
Phone: 281-483-8991
Email: beth.a.fischer@nasa.gov

Inquiries regarding the use of the Communication Systems Simulation Laboratory (CSSL) should be directed to:

Adam Schlesinger
Communication Systems Simulation Laboratory Manager
Johnson Space Center
2101 NASA Parkway, Houston, TX 77058
Phone: (281) 483-0342
Email: adam.m.schlesinger@nasa.gov

Please refer to the Engineering Services Web site, http://www.jsceng.nasa.gov, for additional information and general inquiries about test, analysis, and simulation capabilities at JSC.

1.4 Communication Systems Simulation Laboratory

The Communication Systems Simulation Laboratory (CSSL) is used for modeling and simulation of both proposed and actual spacecraft communication systems, subsystems, components, and parts. The laboratory hosts high-fidelity computer models of communication systems, detailed structure models, three-dimensional (3D) and planar cuts of antenna patterns, planetary terrain models, and propagation models. To compliment analysis in the CSSL, the Computational Electromagnetics (CEM) Laboratory is available for modeling antenna properties. It is also available as a stand-alone service for full vehicle electromagnetic analysis that can be used as verification of microwave and antenna measurements. See the CEM Laboratory Engineering Services page* for details. Additionally, the Electronic Systems Test Laboratory (ESTL) is available for design evaluation, Radio Frequency (RF) interface compatibility, and system performance verification testing of spacecraft RF communications systems and their interfaces with external (e.g., ground stations, relay satellites, detached payloads) elements. See the ESTL Engineering Services page** for details about the ESTL.

CSSL Services Provided
• RF coverage analysis • System design and verification • Communication system performance • Signal analysis • Frequency management • RF compatibility analysis • Multipath analysis • Communication system anomaly resolution

* http://www.nasa.gov/centers/johnson/engineering/integrated_environments/computational_electromagnetics_laboratory

** http://www.nasa.gov/centers/johnson/engineering/human_space_vehicle_systems/ESTL/

2.0 Safety and Health

Safety is an integral part of the culture at the NASA. Management, leadership, and employee involvement from all organizations is critical to the success of NASA's safety program. While visiting JSC, the requester shall follow all facility-specific safety and health requirements. A facility safety briefing shall be provided to all personnel prior to the start of the test. The safety briefing will include a review of the facility safety rules, potential hazards, and emergency procedures.

3.0. Export Controlled and Proprietary Information

JSC provides for protection of export controlled and proprietary information and hardware throughout the analysis process. The CSSL has a private network that is isolated from the local JSC network by a firewall. The Requester shall clearly mark all export controlled or proprietary hardware items, models, and data provided with a notice of restriction on disclosure or usage. The Laboratory Manager shall safeguard export controlled or proprietary items from unauthorized use and disclosure and ensure that they remain secure within the laboratory and are properly sequestered. Access to the laboratory is restricted to facility personnel and escorted visitors. Models shall be returned to the Requester or disposed of in accordance with the Requester's instructions at the completion of the activity. The CSSL facility is not authorized to process Department of Defense (DoD) classified information.

4.0 Simulation Process

The flowchart presented in Figure 1 outlines the basic roadmap and significant milestones between the initial analysis request and delivery of data. The flow is separated between Requester actions and Laboratory actions, highlighting interactions and inputs between the Requester and the Laboratory Manager.

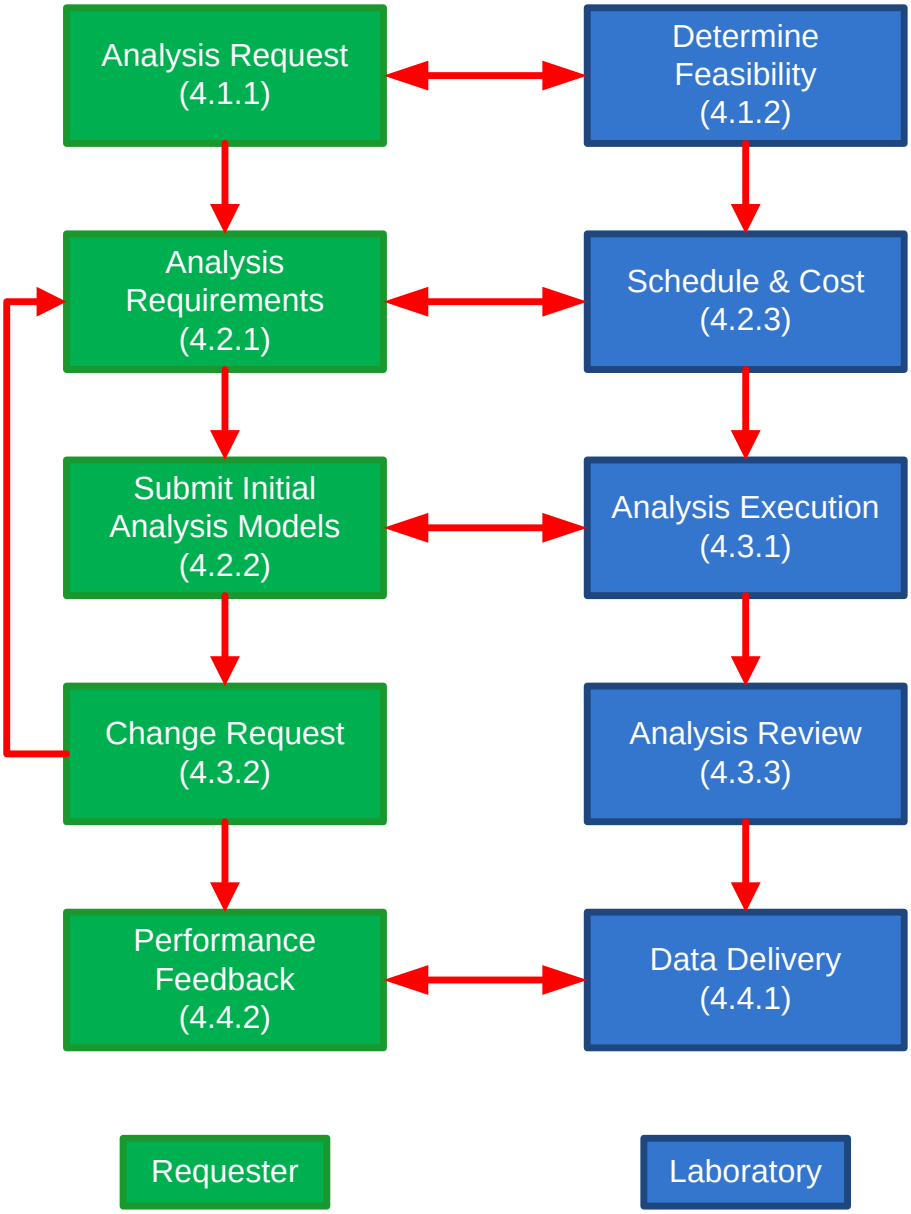


Figure 1. CSSL Analysis Process Flowchart

4.1 Analysis Request Phase

The analysis request phase establishes the relationship between the Requester and the Laboratory Manager. The Requester shall contact the Laboratory Manager to request a simulation analysis. This contact is necessary to identify the quantity or quantities of interest to be determined during the simulation. Once this is done, an estimated cost and work schedule may be developed and provided to the Requester.

Inputs: Requester provides analysis request, identifies simulation goals

Activities: Laboratory Manager reviews request to determine feasibility

Outputs: Laboratory Manager delivers estimated cost and schedule to Requester

4.1.1 Analysis Request

The analysis request outlines the scope of the work, objectives, and schedule. An Analysis Request Worksheet is provided in Appendix B. This worksheet addresses the basic requirements for utilizing the CSSL. It is suggested that the Requester complete this worksheet to facilitate the development of a preliminary cost and schedule estimate. Contact the Laboratory Manager if you have questions about completing the Analysis Request Worksheet. At a minimum, the request should include the following information:

Scope of Work

A brief description of the analysis requirements, including, but not limited to, the following:

- Desired quantities to calculate
- Communication system details (e.g., communication system parameters, trajectory, and attitude for vehicles, satellites, and ground stations)
- Does a Computer-Aided Design (CAD) model exist? (e.g., vehicle structure)
- Data requirements (e.g., primary measurements, data format)

Schedule

Identify the required start and completion dates for the proposed simulation work.

4.1.2 Feasibility Assessment and Schedule and Cost Estimate

The laboratory manager will assess and determine if the requested analysis fits within the capabilities of the CSSL. If deemed feasible, a cost and schedule estimate, including major milestones, will be delivered to the Requester following receipt of the Analysis Request Worksheet.

4.2 Analysis Preparation Phase

Analysis requirements, cost, and schedule are finalized during the analysis preparation phase. The Requester shall provide detailed requirements and documentation to the Laboratory Manager.

Inputs:	Requester provides requirements and documentation
Activities:	Laboratory Manager begins planning the work
	Requester sends models to Laboratory Manager
Outputs:	Requester approves cost and schedule
	Laboratory staff begins analysis

4.2.1 Requirements

A complete understanding of requirements is mandatory. Requirements must be defined and reviewed so that the Laboratory Manager can properly prioritize, plan, and schedule the work. The Requester shall provide a detailed list of requirements, including, but not limited to, the following:

- Simulation model/drawing (CAD preferred)
- Communication systems information (e.g., properties of the materials, frequencies, boundary conditions)
- Desired output data

4.2.2 Documentation

The Requester shall provide detailed simulation article drawings (CAD preferred, if available) as requested by the facility. Simulation article drawings are used to create models for simulation analysis. We can accept files by e-mail, through a File Transfer Protocol Site (FTP) site, or via standard mail.

1. E-mail models/drawings to adam.m.schlesinger@nasa.gov.
2. The Laboratory Manager will send an invitation to the NASA FTP site for uploading and sending files.
3. Mail models/drawings to the Johnson Space Center, Attention: Adam Schlesinger, Mail Code: EV6, 2101 NASA Parkway, Houston, Texas 77058.

4.2.3 Schedule and Cost

A detailed cost and schedule shall be developed by the Laboratory Manager and approved by the Requester. The schedule shall allow adequate time for review and approval of requirements, preparation for the analysis, and delivery of any models. The schedule of other work and maintenance activities will be reviewed and potential conflicts shall be addressed by the Laboratory Manager.

4.3 Analysis Execution Phase

Following receipt of the model(s), the laboratory staff will complete the work.

Inputs: Required model parameters

Activities: Laboratory staff begins simulation

Outputs: Work completed

4.3.1 Analysis Execution

The following section provides work flowcharts for five common analysis/modeling tasks performed in the CSSL. The work flowcharts are defined in Radio Frequency Communications, Electromagnetic Environmental Effects, and Computational Electromagnetic Analysis Work Instruction, EV-022. These tasks include RF Compatibility Analysis, RF Coverage Analysis, Electromagnetic Field Hazard Analysis, Antenna Illumination Model Development, and Antenna Pattern Generation, as presented in Figure 2 through Figure 6 respectively. Other tasks can be performed but will follow the same basic workflow.

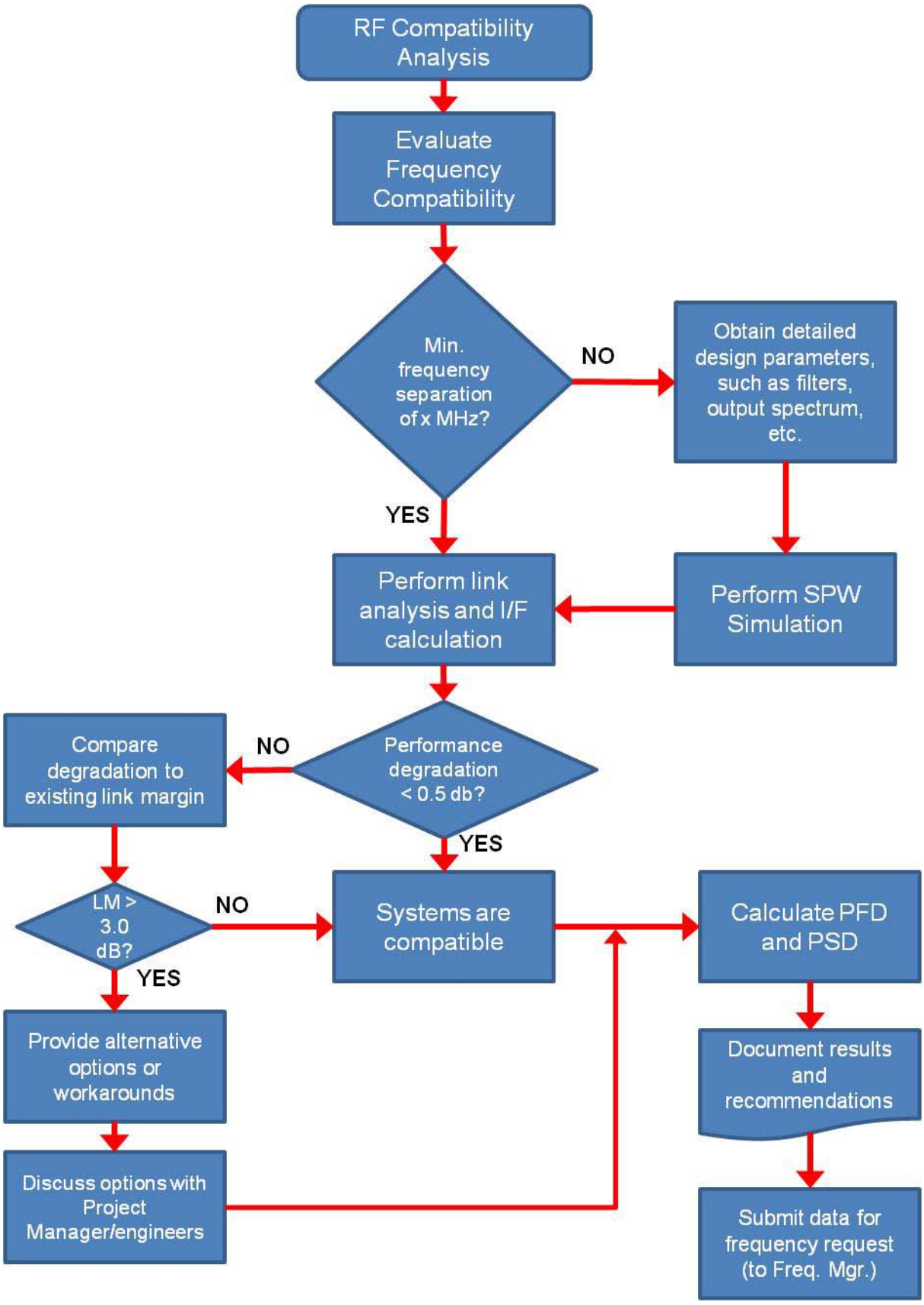


Figure 2. RF Compatibility Analysis Flowchart

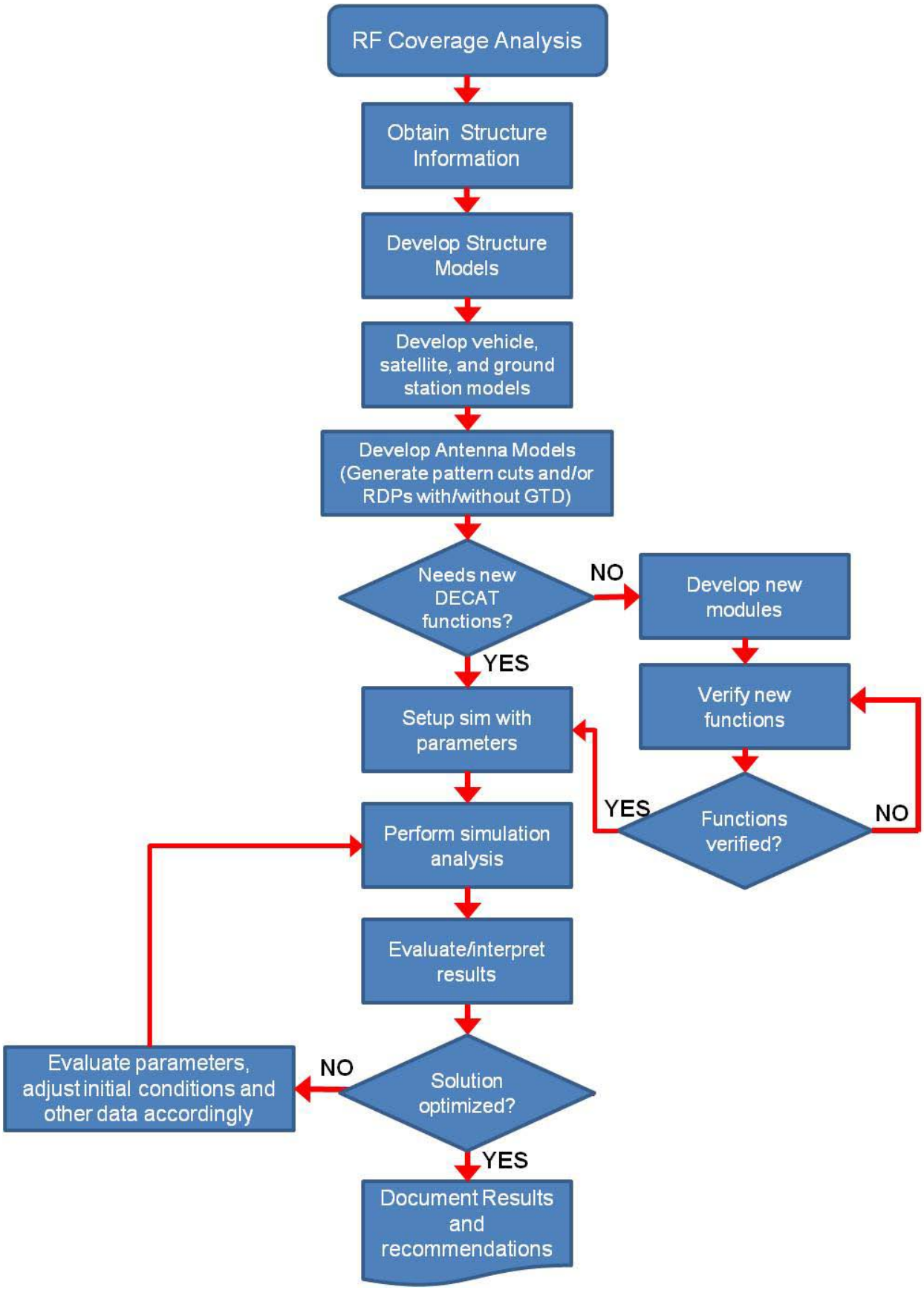


Figure 3. RF Coverage Analysis Flowchart

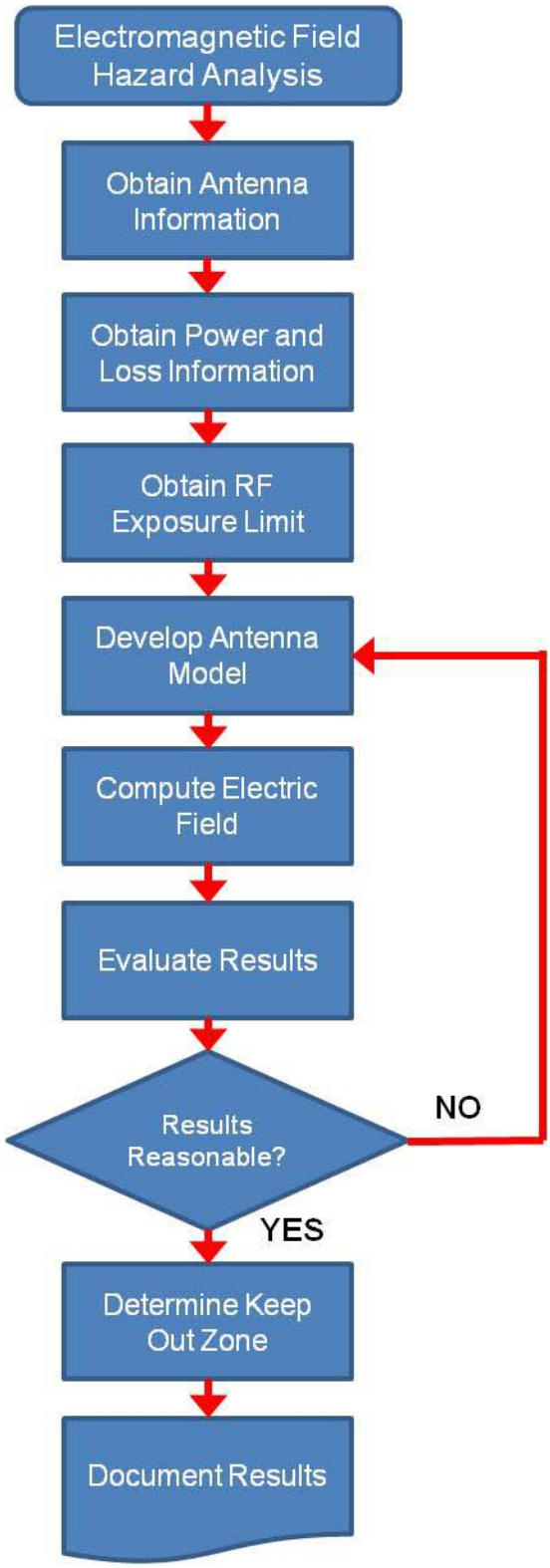


Figure 4. Electromagnetic Field Hazard Analysis Flowchart

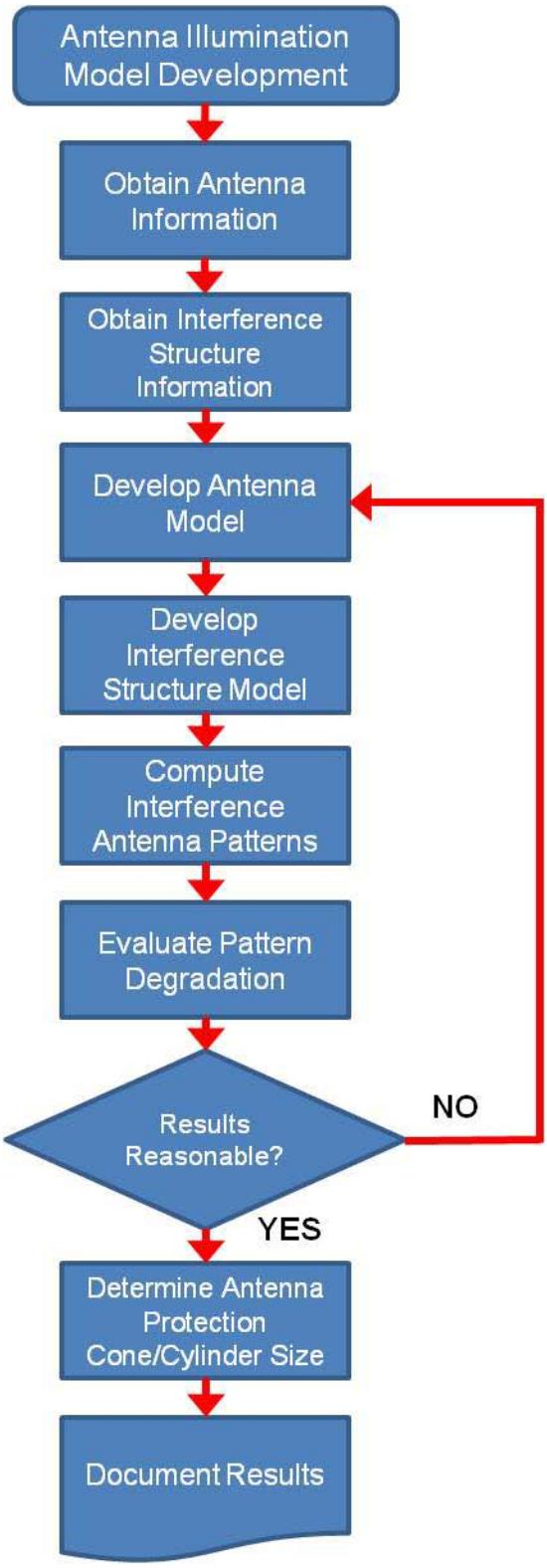


Figure 5. Antenna Illumination Model Development Flowchart

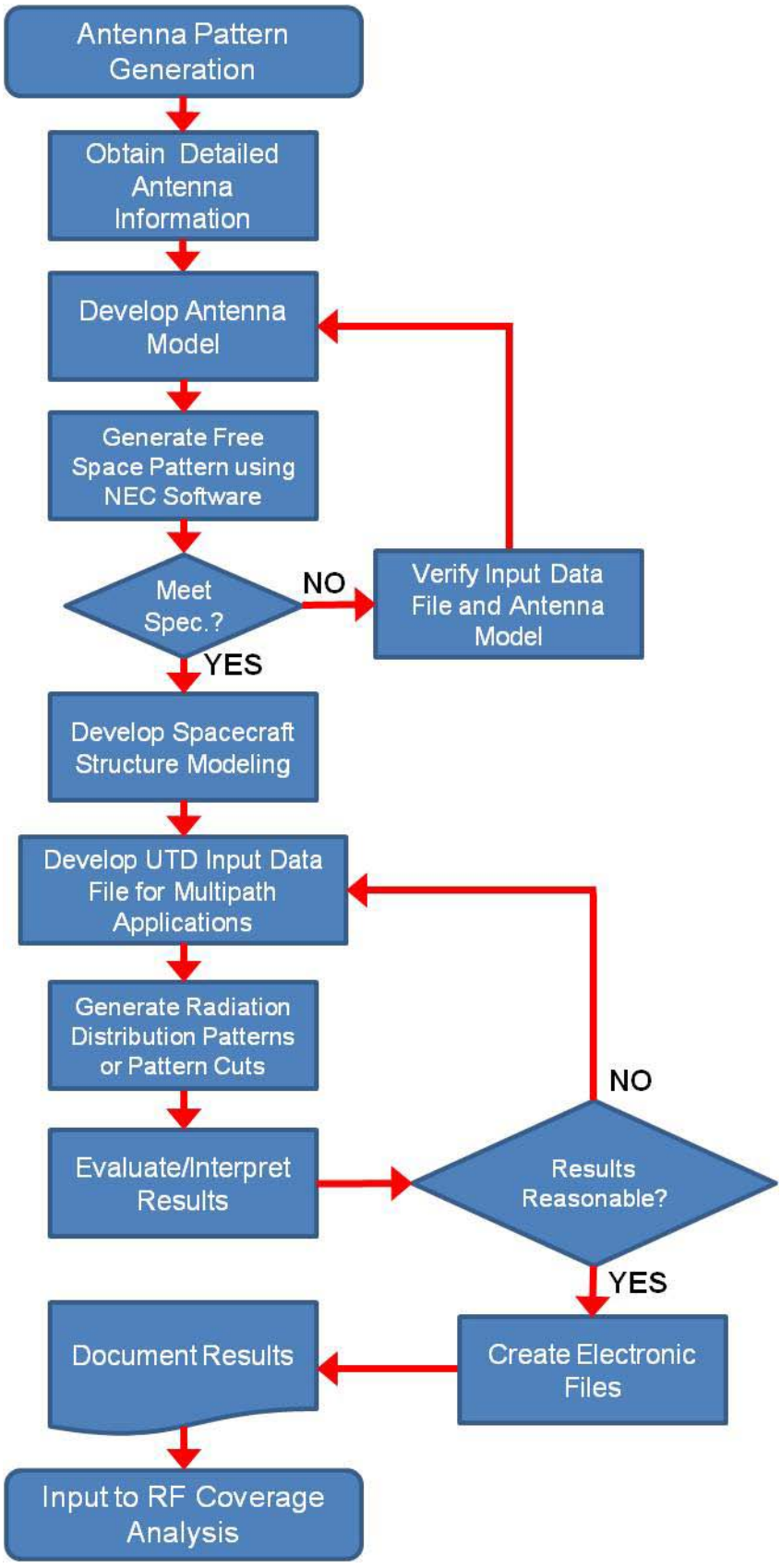


Figure 6. Antenna Pattern Generation Flowchart

4.3.2 Change Request

Changes to the scope of the analysis shall be approved by the Requester. Deviations that result in a major change to the scope of the analysis may require a delta requirements review or a change to the cost and schedule. Changes should be coordinated through the Laboratory Manager.

4.3.3 Analysis Review

After analysis is completed, it will be thoroughly reviewed by CSSL engineers before final documentation is presented to the requester.

4.4 Closeout Phase

Reports and data shall be delivered to the Requester within 30 business days following completion of the analysis. Data delivery may be expedited if requested. The Requester shall notify the Laboratory Manager upon receipt of the data. Acceptance of the data concludes the activity.

Inputs:	Analysis completed
Activities:	Laboratory Manager returns model(s) to Requester
	Laboratory Manager delivers reports and data to Requester
Outputs:	Requester accepts data
	Requester provides feedback

4.4.1 Data Delivery

The final analysis report shall include a definition of the analysis (assumptions, approach, and methodology), initialization data, analysis results, issues and concerns, and conclusions. The Requester shall make note of data delivery and output format requirements in the Analysis Request Worksheet (Appendix B).

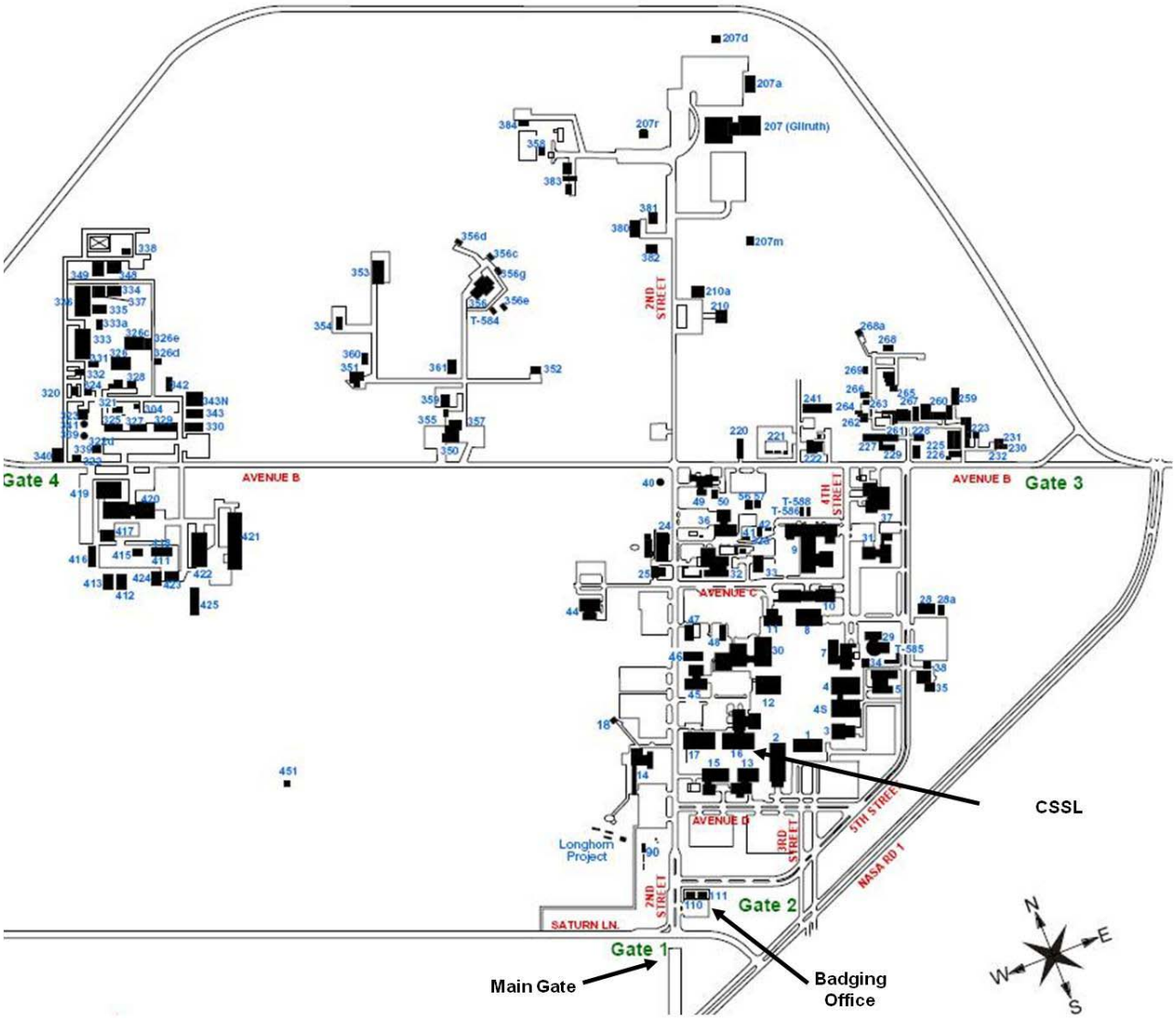
4.4.2 Customer Feedback

The CSSL encourages feedback from our customers. Evaluation of the services we provide enables continued improvement to our process. Please provide any feedback on our services to the CSSL Manager. Your feedback is greatly appreciated.

5.0 Facility Access

Identification badges are required for all persons requiring access to JSC. The Laboratory Manager or designee will initiate a badge request for all Requester personnel who will be visiting the laboratory. Badge requests must be submitted at least 4 days prior to the visit to prevent badge processing delays. Badge requests for non-U.S. citizens may require a minimum of 30 business days to process. Requester personnel shall arrive at JSC Building 110 to pick up temporary identification badges. Visitors to JSC must show a current picture identification (valid driver's license, U.S. passport, government ID card).

The CSSL is located in JSC Building 16, Room 223B.



6.0 Roles and Responsibilities

Laboratory Manager – The CSSL Manager coordinates the overall analysis process via discussions with the Requester.

Laboratory Staff – One or more individuals responsible for performing the analysis per the requirements defined by the Requester.

Requester – The entity requesting a simulation analysis. The Requester is responsible for providing details for the device that is to be simulated.

Technical Expert – A representative of the Requester with thorough knowledge of the requirements. The Technical Expert also is responsible for verifying that objectives are met and for approving change requests.

Responsibilities Matrix

Item	Requester	Laboratory Manager
Analysis Request Worksheet	Create	Review and provide assistance as needed
Cost and schedule	Approve	Create and sign off
Analysis	Approve requested deviations	Perform analysis
Provide data/results	Notify Laboratory Manager of data receipt	Deliver to Requester
Review data/results	Approve	

Acronyms

µs	microsecond(s)
3D	Three-Dimensional
CAD	Computer-Aided Design
CEM	Computational Electromagnetics Laboratory
CSSL	Communication Systems Simulation Laboratory
dB	decibel(s)
DECAT	Dynamic Environment Communications Analysis Testbed
ESTL	Electronic Systems Test Laboratory
FDTD	Finite Difference Time Domain
FTP	File Transfer Protocol
GHz	Gigahertz
GSTDN	Ground Satellite Tracking Data Network
GTD	Geometrical Theory of Diffraction
ID	Identification
ISS	International Space Station
JSC	Johnson Space Center
MHz	Megahertz
MIMO	Multiple Input, Multiple Output
MISO	Multiple Input, Single Output
ms	millisecond(s)
NASA	National Aeronautics and Space Administration
NEC	Numerical Electromagnetic Code
OSI	Open System Interconnection
PFD	Power Flux Density
PSD	Power Spectral Density
R&D	Research and Development
RDP	Radiation Distribution Pattern
RF	Radio Frequency
SIMO	Single Input, Multiple Output
SSCS	Space-to-Space Communication System
STK	Satellite Tool Kit
TDMA	Time Division Multiple Access
UTD	Uniform Theory of Diffraction

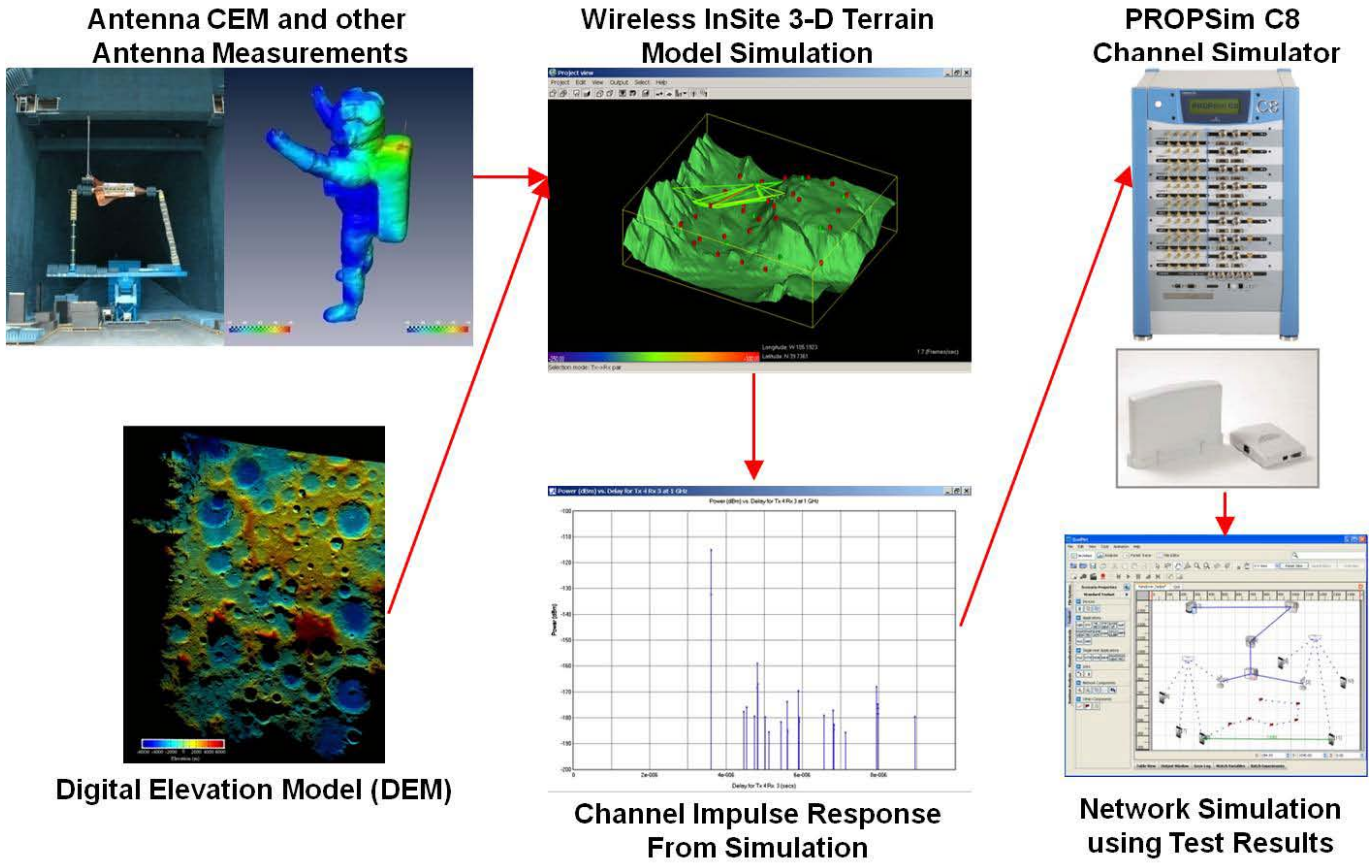
Appendices

A. Communication Systems Simulation Laboratory Tools

B. Analysis Request Worksheet

Appendix A Communication Systems Simulation Laboratory Tools

Architecture for Surface Propagation Analysis and Testing



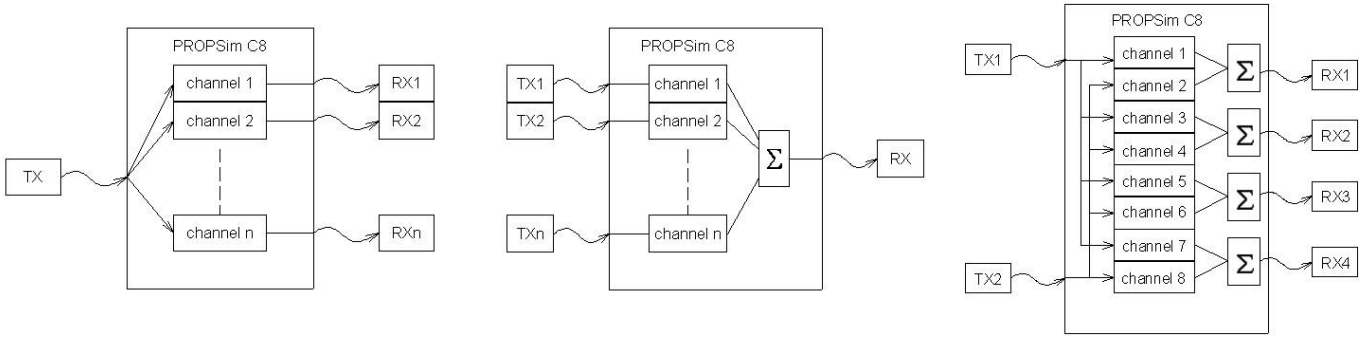
The CSSL makes it possible to integrate antenna data, terrain data, mission profiles and actual hardware to conduct simulations and make real measurements

PROPSim Test Scenarios and Capabilities

- S-Band links, including ranging links
- K-Band high-rate links
- Time Division Multiple Access (TDMA) multipoint links similar to Space-to-Space Communication System (SSCS)

Capabilities:

- Doppler
- Delay
- Multipath and fading channels
- Single Input, Multiple Output (SIMO); Multiple Input, Single Output (MISO); and Multiple Input, Multiple Output (MIMO)
- Bit slips and modulation constellation rotations



PROPSim can internally split and combine channels. It can be used to test SIMO, MISO, and MIMO systems and can also be used to perform interference testing.

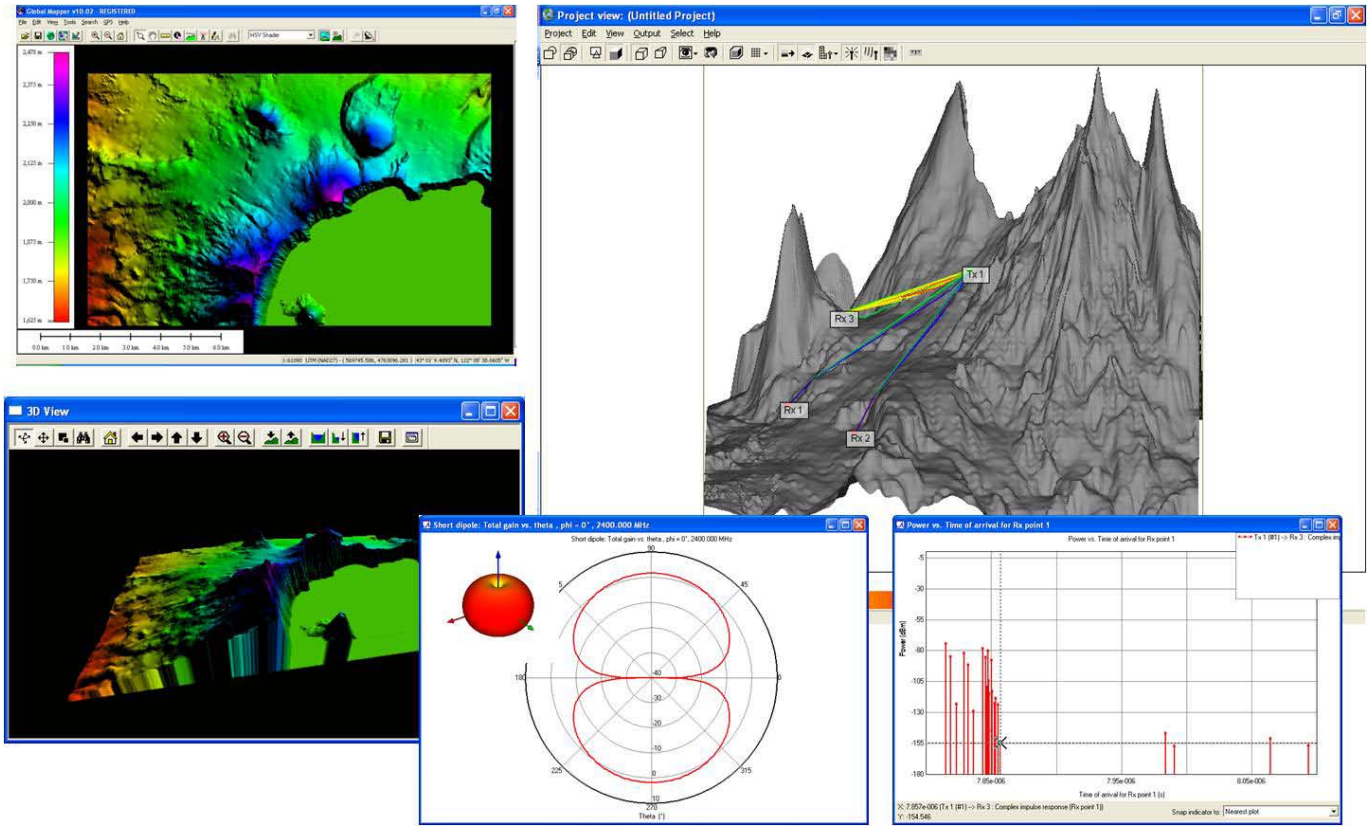
PROPSim C8 Overview

Specifications
• 8 independent channels • RF range of 350 MHz – 6 GHz • Simulation frequency range of 350 MHz – 27 GHz • 48 taps per channel • 70 MHz or 100 MHz bandwidth • 1.3 µs – 6.4 ms of delay • 1 MHz of Doppler

Wireless InSite

Wireless InSite is an RF communication analysis software used to analyze the impact of the physical environment on the performance of wireless communication systems. It provides a broad range of site-specific predictions of propagation and communication channel characteristics in complex urban, indoor, rural, and mixed-path environments. It derives accurate solutions to the underlying electromagnetic wave propagation problem determined by the Uniform Theory of Diffraction (UTD) and Finite Difference Time Domain (FDTD) methods.

Crater Demo in Wireless InSite



Satellite Tool Kit

Satellite Tool Kit (STK) is a tool for analyzing orbits of spaceborne systems and their interactions with ground stations, sensors, and remote objects through animated scenarios. It allows for dynamic link performance analysis, RF environment modeling, use of terrain data, and detailed antenna modeling.

QualNet

QualNet is a high-fidelity network evaluation software that predicts wireless, wired, and mixed-platform network and networking device performance through discrete event simulations.

STK is used for wireless physical layer modeling. STK outputs are fed into QualNet, which models the other layers in an Open System Interconnection (OSI) network stack, to build complete end-to-end communication and network models.

Dynamic Environment Communications Analysis Testbed (DECAT) is used to analytically determine the impact of structural blockage, considering antenna field of view and dynamic structure motion. It is used to dynamically determine interference statistics for on-orbit vehicles with proper modeling of interference sources.

Appendix B Analysis Request Worksheet

Purpose: The purpose of this questionnaire is to provide the Requester with a means of identifying essential elements required to generate a cost and schedule estimate. Please return this form to Adam Schlesinger, Laboratory Manager, adam.m.schlesinger@nasa.gov

Contact Information

Test Article Expert:	Contact Information (Phone, E-mail, Address):

Objectives

Scope of Work:	
Proposed Start Date:	Critical Start Date:

Simulation Overview

Total Number of Simulations:	CAD Provided by Requester (Y/N):
Describe geometry CAD that is already available:	
Desired quantities to be computed in postprocessing analysis:	

Data Acquisition and Recording

Data Handling Requirements (storage, expedited delivery, format):

Other Information

List any other information pertinent to the simulation: